SECOND

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~~SIDEWALL TORSION SENSOR~~
DEVICE FOR ACTIVE-SENSOR SCANNING OF A MAGNETIZED TIRE WITH ENCODER

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to sensors and more particularly relates to sensor assemblies that include signal processing circuitry.

Description of the Related Art

[0002] It is intended to realize a unit for various sensoric arrangements or sensors for the detection of dynamic air gap changes with a general design concept, where the unit comprises shelf parts or ready-made sensors.

[0003] The invention generally serves applications in the area of mechanical engineering, particularly for brake and driving-dynamics systems in the automotive industry, and here primarily in the application sector of controlled systems with brake intervention like ABS and TCS. The main application sector, however, is the employment for ESP (driving stability control systems) and SWT (Sidewall Torsion, in which, for the determination of wheel forces and wheel speed, the tire sidewall deformation of a ~~an~~ motor vehicle wheel is measured via sensors for subsequent evaluation ~~and evaluated~~).

[0004] A specific tire suitable for an SWT or ~~and an~~ SWT sensor, respectively, are known from DE 196 20 582 A1 and DE 196 20 581 A1. Also known in the prior art are magnetically active machine parts for air gap modulation, in which basically all permanent-magnetic or ferromagnetic parts can be utilized, which are moved in the direction of the air gap in dependence on a physical quantity to be measured. Usually, incremental encoders are used for this purpose. There is a distinction between ferromagnetic and permanent-magnetic encoders. Ferromagnetic encoders are, for example, toothed wheels, toothed washers, toothed rings or hole-punched discs. Permanent-magnetic encoders, on the other hand, are usually ring-shaped or circular

arrangements of successive north/south pole areas embedded in rubber or some other mechanical carrier.

[0005] Substantial examples for the use of magnetized encoders are magnetized wheel bearing seals for an ASB system ("Active Sensor Bearing") for the detection of the wheel speed and the magnetized vehicle wheel, already mentioned above, for the detection of dynamic forces according to the SWT principle (Sidewall Torsion Sensors).

[0006] Sensor arrangements for the detection of air gap modulations by means of an encoder are generally known. For instance, they also serve for the determination of crankshaft and camshaft positions in motor vehicle engines. In another typical application for the measurement of wheel speeds, an incremental encoder track periodically modulates the magnetic field strength in the air gap between two fixed values. An additional change of the kinematics between the sensor and the encoder through dynamic forces during driving operation and the herewith additionally occurring modulation of the field strength is undesirable in this application and is suppressed during signal-conditioning.

[0007] To this end, the so-called active sensors known from the prior art for ABS wheel speed detection contain an internal amplifier/trigger circuit such that ~~effects that~~, regardless of the air gap dynamics, always generates a square wave signal ~~with possible states is generated, whose~~ with an edge change that follows the encoder track.

[0008] For the detection of driving-dynamical states (ESP) of a motor vehicle, e.g. during cornering, it is suggested, for example in DE 44 42 355 A1, to draw on the value of an elastic axle deformation and, for its measurement, to use the width of the air gap between a wheel speed sensor and its respective encoder.

[0009] For the determination of longitudinal and lateral forces, it is known from DE 44 35 160 A1 to detect as well the phase of two wheel speed sensor signals as their variable signal amplitudes on a magnetically encoded tire by way of air gap deformations.

[0010] The objective of the present invention is to provide sensors equally suitable for all above-described sensor types, in which concept modular sensor units are formed, whose basic system is suitable for all sensors. It is further the objective of

the present invention t create a sensor, in particular an SWT sensor, suitable for this concept of the formation of common units.

SUMMARY OF THE INVENTION

[0011] A first inventive idea consists in generally designing future sensor units constructively in a way that their housing dimensions and outer shape is identical or nearly identical with sensor elements already in use for the production of active ABS wheel speed sensors (ready to use with cable and plug). This yields the advantage that, for the introduction of series production of novel sensors, e.g. SWT sensors, the same production tools can be used as for active wheel speed sensors.

[0012] Due to the great variety of different series programs for active sensors, there is an abundance of already existing different shape designs and constructive embodiments of active wheel speed sensors with the corresponding production tools, from which matching shapes can be steadily adopted for SWT sensors. In this way, the development expenditure is minimized, and the advantage is attained that also small SWT equipment numbers can be served economically. This basic thought also applies to future active sensors for wheel speed detection.

[0013] Further on, using the above concept, an inventive arrangement is described with which air gap modulations of any kind can be detected so that with these, beside the wheel speed, also air gap changes can be measured as a function of tire sidewall deformation forces. These sensors are particularly suitable for the realization of the tire sidewall torsion concept, yet as well for the realization of sensor systems for ESP based on DE 44 42 355 A1.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] ~~Fig. 1 a shows a basic structure of the inventive sensor unit.~~ FIG. 1A illustrates a sensor unit according to an embodiment of the invention;

[0015] ~~Fig. 1 b-c show different variants of sensors based on the same concept.~~ FIGS. 1B-1D illustrate alternate embodiments of the sensor unit of FIG. 1A;

[0016] ~~Fig. 2 a-b show schematic illustrations of sensor circuits with functional blocks.~~ FIGS. 2A and 2B each illustrate an encoder track arranged on a sidewall of a

magnetized tire that is monitored by a sensor circuit according to an embodiment of the invention; and

[0017] ~~Fig. 3 a-b show the course of signal currents J_1 and J_2 over time.~~ FIGS. 3A and 3B each illustrate a plot of signal currents I_a and I_b over time of the sensor circuits according to FIGS. 2A and 2B, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] In connection with ~~Fig. 1 a-d, at first~~ FIGS. 1A-1D,a general concept for the standardized design of sensor units 10a, 10b, 10c, 10d is described. The sensor units 10a-10d are used for the active-sensor scanning of an encoder~~s~~ 50 arranged in the sidewall of a magnetized tire 75 (FIG. 2A and 2B), which may be a permanent-magnetic-type encoder or a ferromagnetic-type encoder~~is described.~~, ~~which are processed into~~ The sensor units 10a-10d are ready-made sensors (probes)~~, or~~ which may comprise a common modular unit~~s~~, according to an embodiment of the invention~~, respectively~~.

[0019] ~~Fig 1a shows~~ FIGS. 1A-1D show an outer housing shape or basic structure, respectively, of the ~~a general~~ sensor element, which is generally seen at 10a, 10b, 10c, 10d, respectively, according to the inventive design concept. ~~Here reference~~ Reference numeral 12 identifies a first housing~~ or head 1~~, preferably made of plastic, in which a magneto-electric converter element 28a or 28b (FIG. 2A or 2B) is embedded. A second housing 14~~2~~, preferably made of plastic, ~~that is also called body 2. Body 2,~~ contains an ~~some~~ embedded electronic signal processing circuit 30a or 30b (FIG. 2A or 2B). The intended application of the sensor unit 10b-10d determines what type of magneto-electric converter element 28a, 28b is contained in the first housing 12 ~~head 1~~ and what type of signal processing circuit 30a, 30b is contained in the second housing 14~~ in body 2~~. As illustrated, a permanent 4-pole electric connection 16~~3~~ extends between the first housing 12 and the second housing 14~~head 1 and body 2~~. For a 2-wire connection to a control device, a first pin 18~~4~~ serves as signal output and a second pin 20~~5~~ serves as the operating voltage supply element ~~for the supply with operating voltage~~.

[0020] ~~Figures 1b, 1c, and 1dand 1d show the general housing general shape according to Fig. 1a combined with three~~ FIGS. 1B, 1C, and 1D each illustrate alternate embodiments of the sensor unit 10a. As illustrated, each of the sensor units 10b, 10c, 10d include differently sized magnets 22, 24, 26 related to different ~~6, 7, and 8. These magnets serve for the~~ demand-assigned ~~different~~ magnetic pre-loads of the electro-magnetic converters 28a, 28b in the first housing 12~~head 1~~. Following the inventive thought of the design concept, the three different magnets 22, 24, 26~~6, 7, 8~~ have fixed dimensions such that the content of which ~~so that general design variants exist now, whose content~~ can be exchanged or adapted in the first housing 12 ~~head 1 or body 2~~ according to a given ~~the~~ application.

[0021] In an advantageous application, the physical ~~constructive~~ dimensions of the sensor units 10a, 10b, 10c, 10d ~~design variants~~ correspond, at the same time, to the physical dimensions of conventional ~~those of already existing~~ active wheel speed sensors.

[0022] A further advantage of the inventive design concept consists in always realizing the following four interface properties, being: a ~~. A~~ 2-wire connection to ~~the~~ a control device 34a, 34b, an operation with a wide range of uncontrolled supply voltage V_{cc}, a load independent current, I_a or I_b, as a carrier of the output signal, and ~~as well as~~ a continuous frequency resolution up to the standstill of the encoder 50.

[0023] Preferably, magneto-electric converters 28a, 28b are exclusively used, which are based on XMR technologies (concerning this, see Verlag VDI-Technologiezentrum, Düsseldorf, "Technologieanalyse Magnetismus", Vol. 2) such as, for example, ~~. Here particularly~~ AMR technology (anisotropic magneto-resistance) and GMR technology (giant magneto-resistance).

[0024] The design variants of the sensor units 10a-10d shown in FIGS. 1A-1D are consistently used with a significant advantage as follows. For example, the~~: The~~ variant according to ~~Fig. 1a~~ FIG. 1A may be used in combination with a permanent-magnetic encoders 50, the design variant according to ~~Fig. 1b~~ FIG. 1B may be used in combination with a ferromagnetic encoders 50, the design variant according to ~~Fig. 1c~~ FIG. 1C may be used in combination with a ferromagnetic encoders 50, and the

variant according to ~~Fig. 1d~~ FIG. 1D may be used in combination with a permanent-magnetic encoder~~s~~ 50.

[0025] According to another embodiment, ~~Applications of~~ the new design concept related ~~according~~ to the invention are, among others, active wheel speed sensors with digital offset compensation according to patent application DE 198 15 084 A1, in which the first housing 12~~head 1~~ comprises a magneto-resistive bridge 28a, 28b and a barber pole structure as well as an ASIC for digital offset compensation. ASICs are integrated circuits (ICs) specifically designed for the application.

[0026] According to another embodiment ~~Additionally~~, the invention is suitable for active wheel speed sensors with transmission of additional information and a novel data protocol according to DE 196 34 715 A1. For example, the first housing 12 may comprise a ~~A head 1 with~~ magneto-resistive bridge 28a, 28b and barber pole structure, in which an IC or ASIC is employed for the recognition of direction and for the diagnosis of an ~~the~~ air gap, G (FIGS. 2A and 2B).

[0027] The inventive sensor unit 10a, 10b, 10c, 10d can also be employed as an active sensor for the simultaneous detection of wheel speed, ω, and dynamic deformation of the air gap, G ~~deformation~~. The ~~Such a~~ sensor 10a, 10b, 10c, 10d can be utilized with a significant advantage for ESP or SWT, respectively. According to one embodiment, ~~In this case,~~ the sensor unit 10b, 10c, 10d preferably includes the first housing 12 ~~a head 1~~ with a magneto-resistive bridge 28a, 28b and the second housing 14 includes ~~a body 2 with~~ an ASIC, in particular of the type UA1272. Preferably, this embodiment ~~sensor~~ is designed according to one of the design variants illustrated in Figures 1B-1D~~according to Fig. 1 b-d~~.

[0028] As a result ~~Subsequently~~, such a sensor 10a, 10b, 10c, 10d, according to the invention, as well as it adaptation to the inventive concept of the sensor units, is described in further detail . The intended components of realization are mentioned in the preceding paragraph.

[0029] As previously explained, there ~~There~~ are sensor units 10a ~~elements~~ for active wheel speed sensors, which can be integrated into the design concept and are currently manufactured in large numbers. To this end, FIG. 2B ~~Fig. 2b~~ shows a schematic illustration of ~~an electronic~~ sensor circuit 100b with functional blocks of the

~~an~~ active wheel speed sensor unit 10a, and FIG. 2A ~~Fig. 2a~~ shows a schematic illustration of ~~the~~ a sensor circuit 100a, which includes any one of the active wheel speed sensor units 10b, 10c, 10d, according to the invention. As such, FIGS. 2A and 2B each illustrate ~~Both depictions show~~ simultaneous ~~at the same time the~~ constructive allocation and processing of information within the functional blocks into the superordinate design concept according to the sensors 10a, 10b, 10c, 10d illustrated in FIGS. 1A-1D ~~Fig. 1~~.

[0030] Preferably the same crystal module should be used for the detection of the ~~air gap~~ modulation of the air gap, G, that is already present as a standard component of sensor elements for active ABS wheel speed sensors and manufactured in large numbers. This yields the economic advantage that also small SWT equipment numbers can be served more economically. At the same time, the total number of crystal modules produced is increased (reducing the cost per unit).

[0031] As illustrated, the first housing 12 of each sensor circuit 100a, 100b ~~Both head 1~~ contains a magneto-resistive bridge circuit 28a, 28b~~9~~ of the same type. The magneto-electric converters 28a, 28b~~9~~ are, by way of the ~~an~~ air gap, G, ~~not depicted here,~~ magnetically coupled to the ~~a permanent-magnetic~~ encoder track ~~10~~ 50, which may be of a permanent-magnetic-type or ferromagnetic-type that is preferably arranged in the sidewall of a magnetized tire 75 or in a magnetized wheel bearing seal (not shown). ~~The~~ Each first housing 12 is ~~heads 1 are~~ connected to each second housing 14 ~~the bodies 2~~ through the mentioned 4-pole connections 16~~3~~. To the respective control device 34a, 34b, there is the above-mentioned 2-wire connection via the first pin 18~~4~~ and the second pin 20~~5~~.

[0032] The voltage supply V_{cc} is established by way of the respective second pins 20~~5~~ from the ~~an~~ electric control device 34a, 34b or regulating unit for a ~~the~~ brake system. The signal processing circuits 30a, 30b contained in the second housings 14 produce ~~bodies 2 differ by the schematically shown units 12 and 13 so that the signal currents J_1 and J_2 are~~ significantly different signal currents I_a and I_b, respectively.

[0033] In the known active sensor circuit 100b according to FIG. 2B ~~Fig. 2b~~, every fluctuation of amplitude~~,~~ caused by the deformation of the dynamic air gap, G, ~~deformation,~~ is suppressed by an amplifier or trigger stage 32, and the signal current,

I_b is shaped into an accurate, load-independent rectangular signal ~~current J_2~~ with two constant amplitudes so that the transmitted information is limited to the wheel speed, ω, which is mapped in the sequence of edges.

[0034] In the inventive sensor circuit arrangement 100a, ~~according to Fig. 2a,~~ however, there is located an electronic circuit 30a~~12~~ that amplifies and processes ~~amplifying and processing~~ the signal current, I_a, which is ~~so that a signal current J_1 is~~ supplied to the control device 34a~~11~~,. ~~from which~~ The gauge of the amplitude of the signal current, I_a, is gathered to determine a measurement of the ~~additionally, beside the~~ wheel speed, ω, ~~information 14, the gauge of the amplitude can be gathered as a measurement for~~ the thickness of the air gap, G, ~~15~~ and the phase relation, φ_0 ~~16 to a reference signal~~. As a result, reference signals 36, 38, 40 that respectively relate to the wheel speed, ω, the phase relation, φ_0, and the air gap, G, are provided to the control device 34a.

[0035] FIGS. 3A and 3B ~~Figs. 3a and 3b~~ clarify once more the differences of the signal currents I_a and I_b ~~J_1 and J_2~~ between the known active sensor circuit 100b ~~of Fig. 3b~~ and the inventive sensor circuit 100a ~~according to Fig. 3a~~ under the same interface conditions to the encoder 50. Under the presumption of ~~an~~ the air gap, G, variation shown here, both sensor~~s~~ circuits 100a, 100b map the same wheel speed, ω, however, only the inventive sensor circuit 100a ~~additionally~~ also considers the amplitude changing with the width of the air gap, G ~~width~~.

[0036] In an advantageous embodiment of the invention for the realization of an SWT sensor, the previously described arrangement can for instance be designed according to the following characteristics:

- a magnetic sensitivity (output current amplitude/encoder field strength) of S = .75 mA/[kA/m]
- an output current amplitude range of I_a ~~J~~ = 11 mA ± 4 mA lift
- a terminal voltage range at pin 4 of V_{CC} = 5 to 16 V
- an output impedance of 10 kOhm.

[0037] The magnetized tire sidewall 75 with the ~~as~~ encoder 50 ~~track~~ can, for instance, be equipped with a pole pattern of 48 north/south pole pairs per 360^0 tire

sidewall 75 and with a magnetic field strength amplitude of .8 kA/m at 10 mm air gap, G.

[0038] In an advantageous embodiment of the invention for the realization of an SWT sensor, the sensor arrangement is realized according to the inventive design concept by utilizing the following units, being that the~~.~~ first housing 12 ~~Head 1~~ comprises a magneto-resistive bridge 28a, 28b~~9~~, the that the second housing 14 ~~body 2~~ includes an ASIC of the type UA1272. Preferably, the sensor unit 100a is designed according to the embodiments of the sensor units 10b, 10c, 10d illustrated in FIGS. 1B, 1C, or 1D ~~Fig. 1b, 1c, or 1d~~.

[0039] While the invention has been specifically described in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not of limitation, and the scope of the appended claims should be construed as broadly as the prior art will permit.

~~SIDEWALL TORSION SENSOR~~

DEVICE FOR ACTIVE-SENSOR SCANNING OF A MAGNETIZED TIRE WITH ENCODER

ABSTRACT OF THE DISCLOSURE

The invention relates to a sidewall torsion sensor operatively coupled to a sidewall of a vehicle tire to determine the flexation thereof. In order to provide a concept equally suitable for different sensor types, in which modular sensor units are formed and whose basic system is suitable for all sensors, a first housing for the accommodation of at least one converter element (and no signal processing unit), and a second housing for the accommodation of a signal processing unit (and no converter element). A 4-pole connection is provided between the first and second housing, and an output port is provided from the second housing for a control device.

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